Mechanical Testing and Diagnosis
ISSN 2247 – 9635, 2015 (V), Volume 2, pp. 5-11

THE USE OF POLYMERIC MEMBRANES IN WATER FILTRATION

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ABSTRACT

Membrane processes are methods to remove unwanted elements from wastewater stream. Considering this, the water flow is an important parameter to filter waste water and membrane fouling is of great interest in membrane filtration because it reduces wastewater flow passage through the area of the membrane. In order to improve the filtration process, many studies have investigated the use of different concentrations of polymer added in the preparation of polymeric membranes and how much it influences the properties of membranes, like hydrophilicity, permeability and antifouling. One of the most used polymers is polyethersulfone. This paper compares the water flows considering the influence of the polymer concentration, thus, its influence on the properties of membranes used on water filtration.

Keywords: Polyethersulfone (PES), membrane, composite membrane, stability, flow

1. INTRODUCTION

In the process of separation, besides conventional separation processes (distillation, rectification, extraction, ion exchange, filtration, centrifugation, sedimentation), there are a number of other processes, known as membrane processes [1].

Membrane processes have been known since the 70s, when they started a spectacular development, using industrial level in different areas, such as wastewater treatment, medical technology, and chemical industry. The rapid evolution and diversity of these technologies were made possible due to putting in place the experimental techniques for preparing and characterizing the membranes [1].

A complex system consisting of a solvent, in which there are dissolved ionic chemical species, molecules and macromolecules, dispersed macromolecules, molecular aggregates and particles can be separated into its components by membrane processes. Due to their wide range of uses, five important membrane processes could be highlighted covering the entire range of particle sizes, separately, equaling the versatility of sedimentation in the centrifugal field. Membrane separation processes permit and dissolved chemical species, thus, the homogeneous fractionation schemes, resembling, in this respect, to extraction, distillation or ion exchange [2].

Membrane filtration is a way to remove unwanted constituents in the wastewater stream. However, fouling of the membrane is of great interest in the filtration membrane because it reduces the flow of the waste water passing through the portion of the membrane [2]. There are many definitions of the word "membrane", which can significantly vary in complexity and clarity. Three definitions, arbitrarily chosen from the relevant technical literature of the past 20 years are provided below: "An intervention phase separating the two phases and/or acting as a barrier to active or passive transport of material between phases" – European Society for Science and Technology for Membranes (now the European Membrane Society); "An interface of separation between two homogeneous phase and affecting transport of various chemical components in a very specific way" - professor Heine Strathmann, former head of the Department of Membrane Technology of the University of Twente; "A material that some type of substance can pass more easily than others, thus, showing the basis of a separation" - professor George Solt, former director of the School of Water Sciences, Cranfield. Within the meaning of this discussion, in relation to the technology of membranes for treatment of waste water, Solt definition can be considered as adequate: the property which allows the separation membrane and/or water is of vital interest for more membrane processes. In some cases, the membrane may act so as to extract the pollutants from the wastewater, or transfer specific components (such as oxygen) in it [3].

Membrane Separation Technology refers to any membrane separation process, in which functions as both a barrier and a sieve for the separation of feed species, such as liquid mixtures, mixtures of gases and mixtures of colloidal particles [4-7].

Membrane processes occur only in the presence of the driving forces applying to a filtering solution. Possible drivers are differential pressure (Ap), difference of concentration (ΔC), difference of temperature (DT) or difference of electrical potential (ΔE) [8]. In these cases, the membrane is employed to enable selective penetration of specific components dissolved in water. industrial reverse osmosis filtration processes are of great importance, such as (RO), nanofiltration (NF), ultrafiltration (UF) and microfiltration (MF) [3].

In these processes, the water passes through the membrane under an applied pressure, leaving the concentrated pollutants on the impermeable membrane. If we consider the applications of membranes for hemodialysis, the pressure driven filtration processes represent about 75% of sales and is due to membrane treatment applications for municipal and industrial water separation [3].

2. MATERIALS AND METHODS

Polyethersulfone (PES) membrane filters are designed to remove particles during general filtration and for applications in scientific research.

Microporous membranes made of PES are obtained at very high temperatures of the polyethersulfone polymer, which gives resistance to acids and bases [9]. Polyethersulfone membrane (PES) for aqueous solutions ensure the removal of fine particles, bacteria, viruses, fungi, having versatile membrane applications, such as sample preparation, sterile filtration and infusion therapy. Membrane made of PES is a hydrophilic membrane, which provides fast and complete filtration at higher flow rates and high retention capacities. Hydrophilic nature of PES membranes means that there is no need to add surfactants to increase wettability.

Low protein binding nature of PES membrane makes it suitable for biological sample preparation. The availability of a wide range of pore sizes provides the possibility of using these membranes for removing coarse particles in the pre-filter applications or for removing fine particles as a final filter for clarification [10].

In the dead-end filtration, the influent flows perpendicular to the membrane (Fig. 1). Any solid particle in the influent, which is greater than the size of the pores is deposited on the surface of the membrane, forming a layer of "cake" of solid particles. The liquid that passes through the membrane is called filtrate [11].

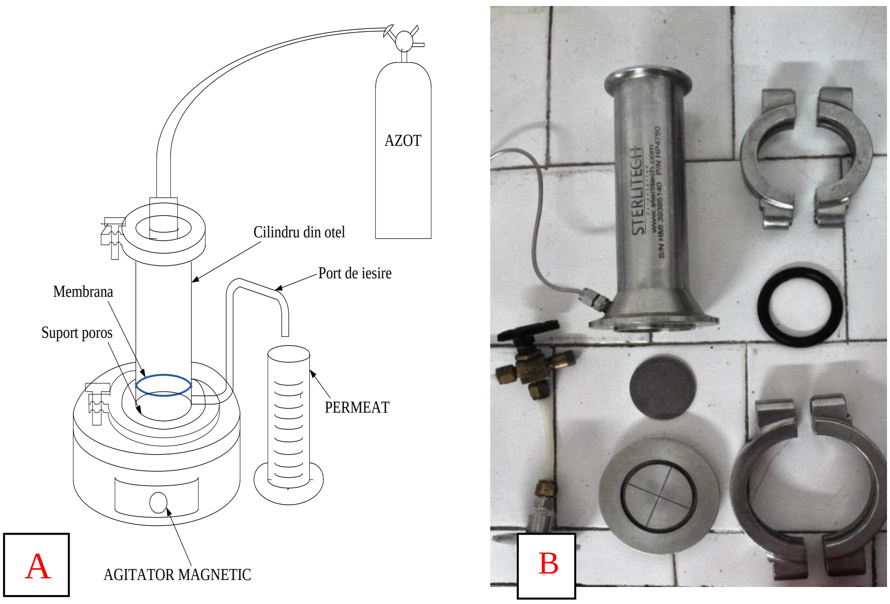

Fig. 1. Dead-End Filtration System: A. Complete filtration plant B. Filtration cell

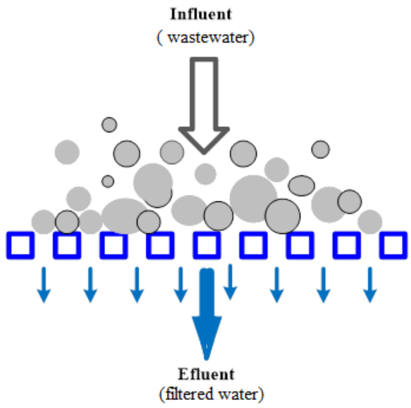

Fig. 2. Dead-End plant filtration process [12]

Most of the dead-end filtration processes are carried out in a discontinued system and, therefore, the mass of "cake" filter increases until all the particles are deposited or until the filter capacity is reached and it is not possible to continue filtering, anymore. The filtration rate decreases in time due to the filter hydraulic resistance of the filter cake formed on the membrane.

The laboratory system for dead-end filtration is often carried out in a filter cell, which is simply a cylindrical vessel, usually made of stainless steel, fitted with a porous support in a shape where the membrane is placed. An output port is provided for the filtrate and it is collected and weighed on a digital balance. For accurate measurements and efficient data collection, the balance can be connected to a computer. The flow is calculated by measuring the mass (and, hence, the volume if the density is known) of the filtrate collected in a known time. The pressure was kept constant by connecting to a compressed air (or nitrogen) source [11].

The dead-end filtration method has the following advantages: the collection rate is high (nearly 100%), miniaturization is possible, cost is low and washing and cleaning is unnecessary [12]. In addition, by optimizing materials and design, the filter life is prolonged.

Ultrafiltration (UF) process is generally similar to the microfiltration process, by configuration and operation [13]. The pore size is between 0.02 mm and 0.1 mm and operates under a pressure ranging from 2 bar to 10 bar. UF is capable of separating many species of bacteria and some viruses, but it can not separate the majority of inorganic ionic species [14]. UF and MF require regular washings (depending on the shape of the membrane). Ultrafiltration is an important technology for purification of water used to produce high purity in industries like biochemistry, food and beverage and biopharmaceuticals. When it is strategically combined with other technologies into a complete water purification system, UF is ideal for removal of colloids, proteins, bacteria and other organic molecules [15].

The membranes were tested for determining the relative flow and, in the same time, the pre-compaction was performed to determine the permeability of membranes.

The determination of the relative flow membrane module was carried out using dead-end filtration, at a constant pressure of 10 bar, for a volume of 250 ml. The value of each type of membrane flux was determined by testing 9 membranes made of four different materials (design solutions). The determination of the flow was performed for different concentrations of polymer in order to see its influence on the flow value. Two different concentrations of polymer (30 wt.% and 32 wt.%) were chosen. After establishing the flow of the simple membranes, ZnO and TiO_2 nanoparticles were added into the polymer solution to determine their influence on membrane properties. The concentration of nanoparticles was set at 0.125 wt.%.

The flow is defined by the ratio of permeate volume that passes through the membrane and the membrane unit area multiplied with time, as shown in equation (1):

$$J = \frac{V}{A*t} \tag{1}$$

where J is the membrane flux, V is the volume of permeate, A is the surface area of the membrane and t is the time of filtration.

Flow is a very important indicator for the performance of the membrane. A high flow is the consequence of a rapid filtration, therefore, sometimes, it helps reducing the operational costs and design solution implementation [16].

3. PREPARATION OF THE SAMPLES

To produce the composite membranes, various processes can be put into practice, such as coating, spinning, self-assembly, deposition and interfacial polymerization. Widely, the most used methods of manufacturing composite membranes are coating and interfacial polymerization [17].

The process for obtaining composite membranes by interfacial polymerization is used because it exceeds the barriers traced to asymmetric membranes obtained by phase inversion [18]. The polymer solution was poured into a thin layer and immersed in a bath of non-solvent (water). The non-solvent (water) layer broadcasted in the film and broadcast solvent solution in coagulation bath, thus, causing the precipitation of the polymer and membrane formation [19].

The prepared composite nanofiltration membranes have recorded excellent properties on the degree of fouling and resistance to chlorine, recommending them to be used in separation and purification in many industrial and wastewater treatments [20].

4. RESULTS

The process for determining the ~~the~~ flow value of a polymeric membrane consists of filtering a quantity of 250 ml of distilled water, under a pressure of 10 bar.

For a more accurate determination, it is considered that the value of the flow is constant in time, considering that the membrane reaches an equilibrium state. By making tests on several types of membranes, it was found that the membranes have different properties, depending on the concentration of the polymer in the composition. Thus, a low concentration of polymer offers a little stability, specifically, a value of 25 wt.% PES.

Analyzing the flow variation for different membranes (Fig. 4), it is noted that with the increase of polymer concentration, the membrane flux has lower values. The highest membrane flux is obtained when the polymer concentration is 30 wt.% PES. Thus, a membrane with higher concentration of polymer has an increased mechanical strength and, therefore, a lower flow.

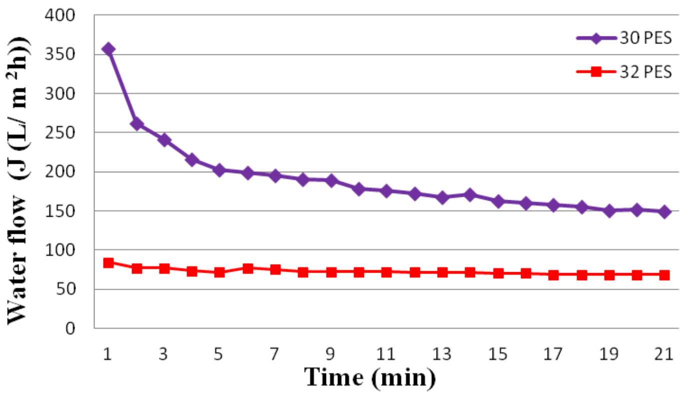

Fig. 4. The pure water flux evolution for PES membrane with different concentrations of the polymer

The flows of different polymer membranes, when they reach equilibrium state, can be compared to each other in order to investigate the influence of the polymer concentration. Analyzing in detail the flux values of the types of PES membrane with 30 wt.% concentration (Fig. 5), we observe that the flow reaches a maximum value of 357.39 $l/(m^2h)$ and stabilizes between the values of 127.11 $l/(m^2h)$ and 125.82 $l/(m^2h)$.

Thus, we can say that the membrane with a concentration of 30 wt.% PES polymer shows a relatively high instability and that the difference is very high between the flow value at the beginning and the flow value towards the end of the test.

By testing under the same pressure of 10 bar and 250 ml of pure water, we noticed differences in the flow values, between the PES membranes with polymer concentrations of 30 wt.% and 32 wt.% Thus, for example, the membrane with the concentration of 32 wt.% PES (Fig. 6) has the maximum flow of 84.45 $l/(m^2h)$ and the minimum value is 68.5 $l/(m^2h)$, whereas there is a much higher stability of this membrane and, therefore, a higher mechanical strength.

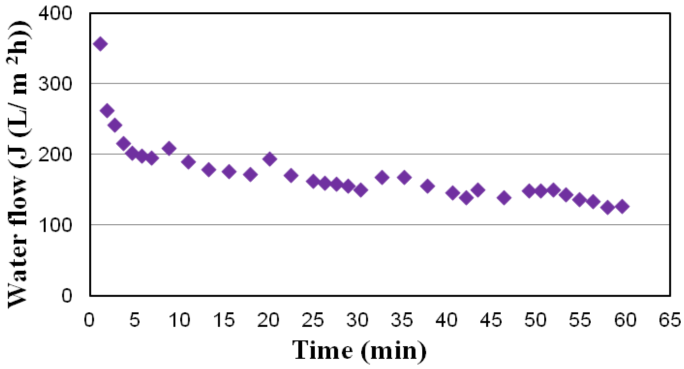

Fig. 5. The pure water flux evolution value for 30 wt.% PES concentration

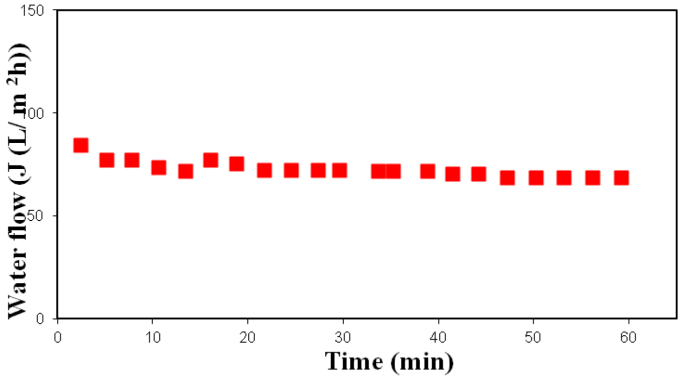

Fig. 6. The flow value for 32 wt.% of PES concentration

5. CONCLUSIONS

In conclusion, analyzing Fig. 7, presenting PES membranes with different polymer concentrations, we notice that the value of the flow decreases as the polymer concentration increases. As it is noticed, the PES polymer membranes with a concentration of 32 wt.% recorded lower flow, but provided a good stability of the membrane, in terms of mechanical property, qualitatively higher. The membrane made of the same polymer, but with 30 wt.% concentration, has great flow values, but low mechanical properties.

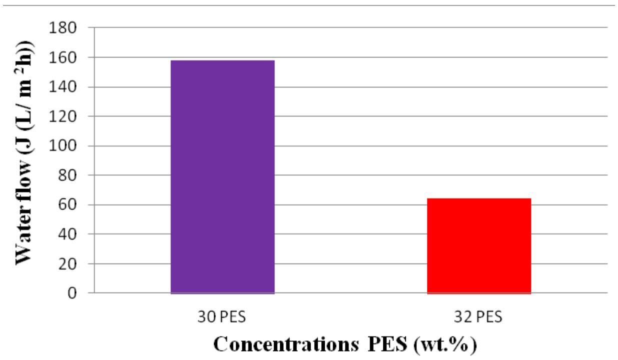

Fig. 7. The influence of polymer concentration on the flux of the PES polymer membranes

Selecting the optimal concentration of polymer is influenced by the application for which the membrane is prepared, according to the pollutants that we want to remove. Membranes with lower concentration of 27 wt.% PES have a high instability in time and, therefore, they may not be effectively used.

REFERENCES

[1] Membrane si procese de membrana, http://www.cttecotech.ro/pdf/fisamembrane.pdf

[2] Nelson H. M., Performance of polymeric membrane systems in the treatment of poultry processing plant waste effluent, 2006, Athens, Greece, https://getd.libs.uga.edu/pdfs/nelson_heather_m_200612_phd.pdf

[3] Rogoveanu (Radosavlevici) I., Robescu D. N., Epurarea apelor uzate utilizând tehnologii membranare, Ecoterra, no. 29, pp. 79-89, 2011, Bucharest.

[4] Mulder M., Basic Principles of Membrane Technology, second ed., Kluwer Academic Publishers, Netherlands, 1998.

[5] Sirkar K.K., Membranes, phase interfaces, and separations: novel techniques and membranes – an overview, Ind. Eng. Chem. Res. 47 (2008) pp. 5250–5266.

[6] Koros W.J., Evolving beyond the thermal age of separation processes: membranes can lead the way, AIChE J. 50 (2004) pp. 2326–2334.

[7] Baker R.W., Research needs in the membrane separation industry: looking back, looking forward, J. Membr. Sci. 362 (2010) pp. 134–136.

[8] Alsalhy Q. F., Ali J. M., Abass A. A., Rashed A., Van der Bruggen B., Balta S., Enhancement of poly (phenyl sulfone) membranes with ZnO nanoparticles, Desalination and Water Treatment (2013) pp. 6070-6081.

[9] PES (Polyethersulfone) Membranes, http://www.sterlitech.com/membrane-disc-filters/polyethersulfone-pes-membranes.html

[10] Polyethersulfone Membrane (Hydrophilic), http://www.pall.com/main/oem-materials-and-devices/product.page?id=3949

[11] Mhurchú J. N., Dead-End and crossflow microfiltration of yeast and bentonite suspensions: experimental and modelling studies incorporating the use of artificial neural networks, PhD thesis, Dublin City University, 2008.

[12] Dead-End Filtration Method, http://www.disco.co.jp/eg/solution/library/dwr_deadend.html

[13] Rautenbach R., Albright R., Membrane Processes, John Wiley & Sons, 1989.

[14] Lahlou M., Membrane Filtration as an Alternative: Part 1, Water Engineering and Management, 2000.

[15] Mulder M., Basic Principles of Membrane Technology, Kluwer Academic, 1997.

[16] Radev I. R., Koutzarov K., Pfrang A., Tsotridis G., The influence of the membrane thickness on the performance and durability of PEFC during dynamic aging, *International Journal of Hydrogen Energy*, 37(16), August 2012, pp. 11862–11870

[17] Balta S., Sotto A., Kim J., Luis P., Benea L., van der Bruggen B., 2012, A new vision on membrane enhancement with nanoparticles: the alternative of ZnO, *Journal of Membrane Science*, vol. 389, pp. 155-161.

[18] Li S., Wang Z., Zhang C., Wang M., Yuan F., Wang J., Wang S., Interfacially polymerized thin film composite membranes containing ethylene oxide groups for CO_2 separation, *Journal of Membrane Science*, vol. 436, 2013, pp. 121–131.

[19] Zhang Y., Su Y., Peng J., Zhao X., Liu J., Zhao J., Jiang Z., Composite nanofiltration membranes prepared by interfacial polymerization with natural material tannic acid and trimesoyl chloride, *Journal of Membrane Science,* 429, 2013, pp. 235–242.

[20] Alpatova A., Kim E.-S., Sun X., Hwang G., Liu Y., G. El-Din M., Fabrication of porous polymeric nanocomposite membranes with enhanced anti-fouling properties: Effect of casting composition, *Journal of Membrane Science*, vol. **444**, 2013, pp. 449–460.